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ANALYSIS OF STABILITY OF POLISHED SHEET GLASS PRODUCTION

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A method for analyzing the effects of modifications in the technological conditions of glass melting on the properties and defects of polished glass is proposed.

The production of polished glass is characterized by a continuous production process and large-capacity output with a relatively limited glass thickness range. The stability of the technological process is characterized by the mathematical expectation value and the mean quadratic deviation of the properties and defects of the glass produced in the analyzed time period. The arithmetical mean of the parameters is used to estimate their mathematical expectation. In the case of the normal law of distribution and a stationary production process, the mean value of a parameter and its mean quadratic deviation are sufficient as estimates of the process stability. The mean value characterizes the average parameters of the produced glass in the analyzed period, and the mean quadratic deviation characterizes the stability of the process.

In the case when the technological process is affected by substantial disturbances, or when some corrections are introduced into the technological regulations of the machinery, point estimates, such as the arithmetical mean and the mean quadratic deviation, are not sufficiently informative, since they do not identify the changes which took place. Disturbances in the stationary process can be caused also by other reasons, such as alterations in the properties of the materials used in the process, modifications in the technological equipment design, etc.

In order to identify the specified effects, we suggest an analysis of the characteristic peculiarities of the distribution density of the probability of the analyzed parameters. To accomplish this, one needs nonparametrical approximation of the respective statistical law.

The essence of the method used for approximation of the density function is as follows. Let x_1, \dots, x_n be the ranked values of the monitored parameter, whose density $f(x)$ is unknown. It is demonstrated in [1] that each interval (x_i, x_{i+1}) is inversely proportional to the true density function, and the proportionality coefficient is a random value with known

density. These intervals are used to construct the secondary sample:

$$(z_1, \ln f_1^v), \dots, (z_{n+1}, \ln f_{n+1}^v),$$

which corresponds to the additive model

$$\ln f_i^v = \ln f(z_i) + \xi_i,$$

where z_i are the points in the intervals (x_i, x_{i+1}) ; ξ_i are the centered errors, for which the covariation matrix is known from the construction.

Thus, each f_i^v value is considered as a direct observation of the density logarithm.

The resulting secondary sampling is intended for further approximation of the density logarithm employing the means of regression analysis. For this purpose, the set of polynomials with power basis functions is used to select a polynomial which satisfies the Mallows criterion minimum [2]. The resulting function, which approximates the proper density function $f(x)$ and not its logarithm, is obtained by taking antilogarithms of the optimal polynomial.

The efficiency of the described method for analyzing the stability of the glass production process can be illustrated by analysis of the optical properties of glass manufactured on the polished glass production lines at the Borskii Glass Works JSC in 1999 (Fig. 1).

The optical properties of glass are measured by the Zebra method in degrees. The shapes of the variations in the optical properties of the produced glass with time are similar. The difference consists in the mathematical expectation and the mean quadratic deviation of the parameters. Thus, glass made on the second line has better optical properties. The arithmetical mean determined by the Zebra method is 61°, and the mean quadratic deviation is 4°. Glass produced on the first line is characterized by an arithmetical mean of 50° and a mean quadratic deviation of 8°.

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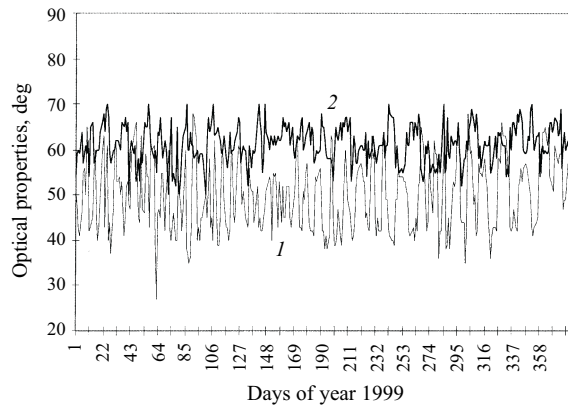


Fig. 1. Optical properties of glass produced on LPS1 (1) and LPS2 (2) lines.

Analysis of the distribution densities of the optical properties of glass revealed a non-stationary functioning of the first production line in year 1999. (Fig. 2). The shapes of the variations of glass optical properties differ significantly for production lines LPS1 and LPS2. Thus, the distribution density of the optical properties of glass made on the first line is bimodal, which is evidence of its nonstationary operation. The plot exhibits two distribution centers with modes of 42° and 56° . Unlike that, the distribution density of the optical properties of glass produced on the second line is monomodal with a value of 61° , which points to the stability of the production process.

Subsequent analysis of the performance of two production lines made it possible to identify the reason. Due to the shortage of recyclable glass cullet, starting with September 1999, the amount of cullet fed into the tank furnace of line 1 was gradually reduced, whereas the amount of cullet charged into the line 2 tank furnace remained constant. The cullet charge in the first furnace decreased from 31% in September to 25 – 20 – 15% in October. The modification of the technological conditions on the first line led to a corresponding modification in the optical parameters of the produced glass.

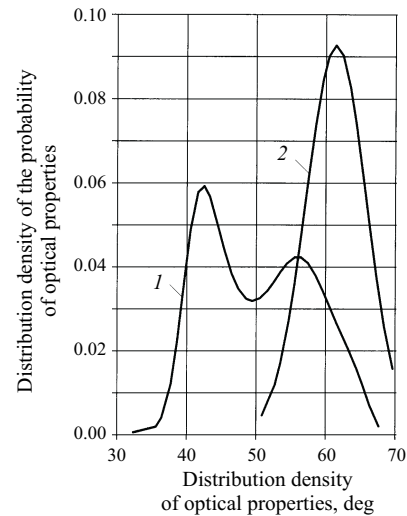


Fig. 2. Distribution density of the probability of the parameter determined by the Zebra method for LPS1 (1) and LPS2 (2) production lines.

The arithmetical mean of the glass optical properties increased from 49 to 52° , and the mean quadratic deviation changed insignificantly from 7.6 to 8.2° .

The analysis of other operating parameters also revealed the effect which the modification of the operating conditions of the first production line had on the properties and defects of the finished glass, which confirmed the expediency of using the density of parameter distribution probability to estimate the stability of production line performance in production of polished glass.

REFERENCES

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2. C. L. Mallows, "Some comments on C_p ," *Technometrics*, **15**(4), 661 – 675 (1973).